MULTIPARAMETER RADAR ESTIMATION OF RAINDROP SIZE DISTRIBUTION

Final Report (Amended)

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September 1, 1989

U.S. Army Research Office

DAAL03-86-K-0117

Colorado State University

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARO 23935.5-GS
6a. NAME OF PERFORMING ORGANIZATION Colorado State University 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U. S. Army Research Office
6c. ADDRESS (City, State, and ZIP Code) Fort Collins, CO 80523	7b. ADDRESS (City, State, and ZIP Code) P. O. Box 12211 Research Triangle Park, NC 27709-2211
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U. S. Army Research Office 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAL03-86-K-0117
8c. ADDRESS (City, State, and ZIP Code) P. O. Box 12211 Research Triangle Park, NC 27709-2211	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Multiparameter Radar Estimation of Raindrop Size Distributions

12. PERSONAL AUTHOR(S)
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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 86/6/1 TO 89/5/3	89/8/7	

16. SUPPLEMENTARY NOTATION
The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Radar, Polarization, Raindrop, Rainfall, Differential Reflectivity, Attenuation, Axis Ratio, Oscillations

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The error structure of multiparameter radar and surface disdrometer measurements of rainfall has been studied in detail. The radar observables studied were reflectivity, differential reflectivity and X-band specific attenuation. These radar observables were simulated from fundamental considerations which incorporated statistical fluctuations due to the Doppler spectrum and the cross-correlation between H and V-polarized signals at zero time lag. Additionally, natural variations in the raindrop size distribution were incorporated into the simulations by assuming a gamma form for the size distribution with parameters (N_0,D_0,m). Thus, the radar simulations contain the effects of both statistical fluctuations and physical variations. The simulation results produce realistic scatter as observed with data acquired by the NCAR CP-2 radar.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Surface disdrometer measurements were also simulated accounting for the Poisson and Gamma distributed nature of the drop samples. Sampling fluctuation as well as physical variabilities of the drop size distribution were incorporated into disdrometer simulations. An intercomparison of these simulated variables revealed the nature and reason for certain inconsistencies reported in the literature by various authors. Our study showed that the use of differential reflectivity does indeed improve the characterization of the median drop size, and that its use in rainfall rate estimation will increase the accuracy by approximately a factor of 2 over conventional reflectivity based methods. This improvement could not be detected in radar/disdrometer intercomparison experiments because of the stochastic nature of the surface data, i.e., the Poisson and Gamma statistics of the raindrop samples introduces random fluctuations very different from the radar fluctuations thus masking any potential improvement predicted from theoretical arguments.

In 1987, Colorado State was chosen as a Center for Excellence in Geosciences by the ARO giving added impetus to multiparameter radar studies already initiated by the authors of this report. A substantial amount of research into the new measureable termed differential propagation phase (ϕ_{DP}) and its range derivative termed specific differential phase (K_{DP}) was initiated using time series data from the CP-2 radar. Using experimental data it was shown that in rainfall the X-band specific attenuation bears a direct, linear relationship to S-band ϕ_{DP}. Simulations showed that S-band ϕ_{DP} could be used to predict rainfall attenuation up to 35 GHz. S-band ϕ_{DP} in the stratiform ice phase up to 1° km^{-1} were also measured and interpreted as being due to oriented ice crystals of the plate type. The error structure of K_{DP} was studied using simulation techniques developed earlier and it was shown that the three rainfall estimators based on reflectivity, Z_{DR} and K_{DP}, termed respectively, R(Z), $R(Z,Z_{DR})$ and $R(K_{DP})$ have different ranges of applicability. For rainrates < 20 mm hr^{-1}, R(Z) appears to have the least error; for 20 < R < 70 mm hr^{-1}, $R(Z,Z_{DR})$ appears optimum while for R > 70 mm hr^{-1}, $R(K_{DP})$ is optimum. These ranges reflect combined error sources due to, (i) drop size distribution fluctuations and (ii) random errors in Z, Z_{DR} and K_{DP}.

We have analyzed the axis ratio of raindrops as function of their size using 2D-PMS probe images of drops in convective rainshafts. Axis ratios were estimated for about 3500 drops using the Fourier descriptor technique. Drops with diameters less than 4 mm were found to be slightly more spherical than would be expected for drops in equilibrium. Oscillation amplitudes were found to be typically $\pm 10\%$ in axis ratio for light-to-moderate rainfall rates, and such oscillations can account for departures from equilibrium values. We have determined that differential reflectivity can be used to estimate the volume median diameters of almost-exponential spectra to an accuracy of about 0.3 mm. Without this information, rainrates based on reflectivity alone could be in serious error.

Journal Publications

(1) Chandrasekar, V., W. A. Cooper and V. N. Bringi, 1988: Axis Ratios and Oscillations of Raindrops, J. Atmos. Sci., Vol. 45, No. 8, pp. 1323-33.

(2) Chandrasekar, V. and V. N. Bringi, 1987: Simulation of Radar Reflectivity and Surface Measurements of Rainfall," J. Atmos. Ocean. Tech., Vol. 4, No. 3, pp. 464-478.

(3) Chandrasekar, V. and V. N. Bringi, 1988: Error Structure of Multiparameter Radar and Surface Measurements of Rainfall, Part I: Differential Reflectivity, J. Atmos. Ocean. Tech., Vol. 5, No. 6, 783-795.

(4) Chandrasekar, V. and V. N. Bringi, 1988: Error Structure of Multiparameter Radar and Surface Measurements of Rainfall, Part II: X-Band Attenuation, J. Atmos. Ocean. Tech., Vol. 5, No. 6.

(5) Chandrasekar, V., V. N. Bringi, N. Balakrishnan and D. S. Zrnic, 1989: Error Structure of Multiparameter Radar and Surface Measurements of Rainfall, Part III: Specific Differential Phase, accepted for publication in J. Atmos. Ocean. Tech., (in press).

Conference Proceedings

(1) Golestani, Y, V. Chandrasekar and V. N. Bringi, 1989: Intercomparison of Multiparameter Radar Measurements, Preprints 24th Conf. Radar Met., AMS, Tallahassee, 309-314.

(2) V. N. Bringi, V. Chandraseskar and Y. Golestani, 1989: Polarimetric Radar Observations in Convective Storms, NATO ARW on Direct and Inverse Methods in Radar Polarimetry, Bad Windsheim, FRG (to appear in a book, ed. W. Boerner).

(3) V. Chandrasekar and P. J. Brockwell, 1989: Simulation of a Class of Exponential Time Series Using Innovations, Computer Science and Statistics, 21st Symp. on the Interface ASA, Washington, D. C.

(4) V. Chandrasekar and P. J. Brockwell, 1988: Inference Techniques for a Class of Exponential Time Series, Computer Science and Statistics, 20th Symp. on the Interface, ASA, Washington, D.C.

Degrees Awarded

Name	Degree	Date	Thesis Title
V. Chandrasekar	Ph.D.	Spring 1987	Some Uncertainties in the Multiparameter Radar Measurement of Rainfall.
R. Raghavan	M.S.	Fall 1987	Analysis of Multiparameter Radar Measurements in Convective Storms.

Other Students Supported

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